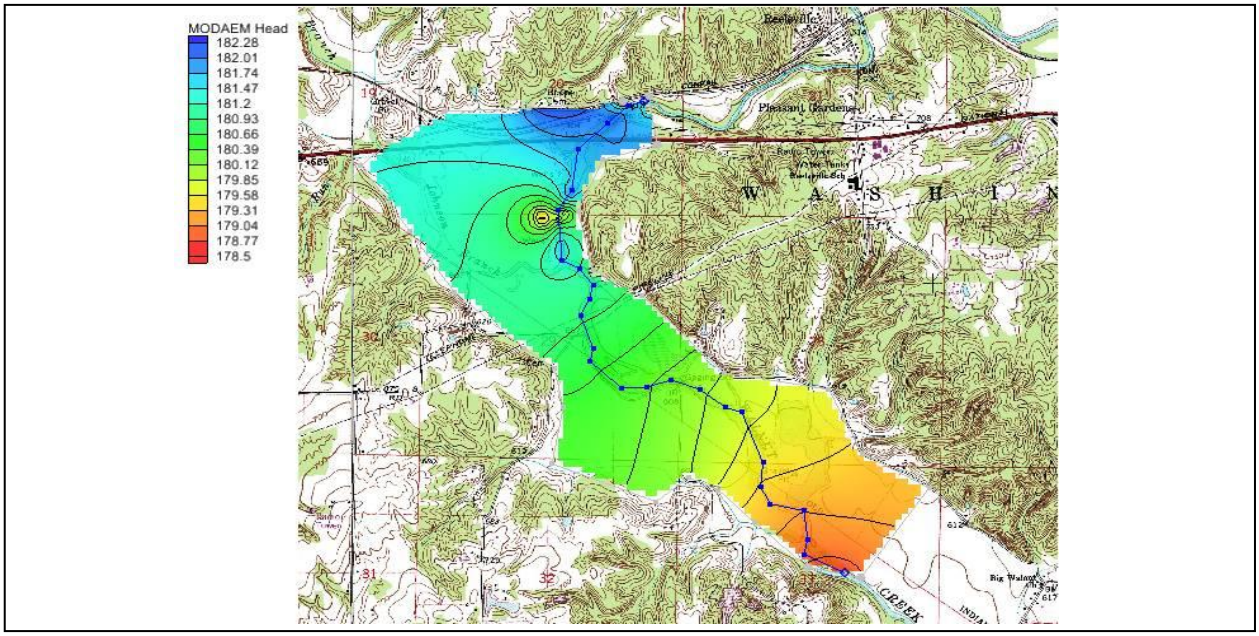
GMS 10.3 Tutorial
MODAEM
Analytic element modeling with MODAEM



Objectives
Illustrate the use of GMS for analytic element modeling with MODAEM.

Prerequisite Tutorials
- Feature Objects

Required Components
- Map Module
- MODAEM

Time
- 25–40 minutes

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1 Introduction

MODAEM is a single-layer, steady-state analytic element groundwater flow model that has been enhanced for use with GMS. This chapter introduces MODAEM and illustrates the use of GMS for analytic element modeling. This tutorial does not go into detail in explaining the analytic element method. For a more detailed explanation of analytic element modeling and MODAEM, refer to the MODAEM Help manual.

This tutorial will go over reading in a background map, creating a conceptual model and define the parameters, and finally running MODAEM for different conditions.

1.1 Description of Problem

This tutorial describes the use of GMS to model groundwater flow near the well field of Brazil, Indiana, USA. Brazil (population 8,188) operates a well field about five miles east of town, in the floodplain of Big Walnut Creek (see Figure 1). The objectives of this model are to do the following:

- Model the 5-year capture zone for the wellfield for use in the Brazil wellhead protection effort.
- Examine the effects of the addition of a well to the wellfield.

The following figure shows the site location, along with the model boundaries.

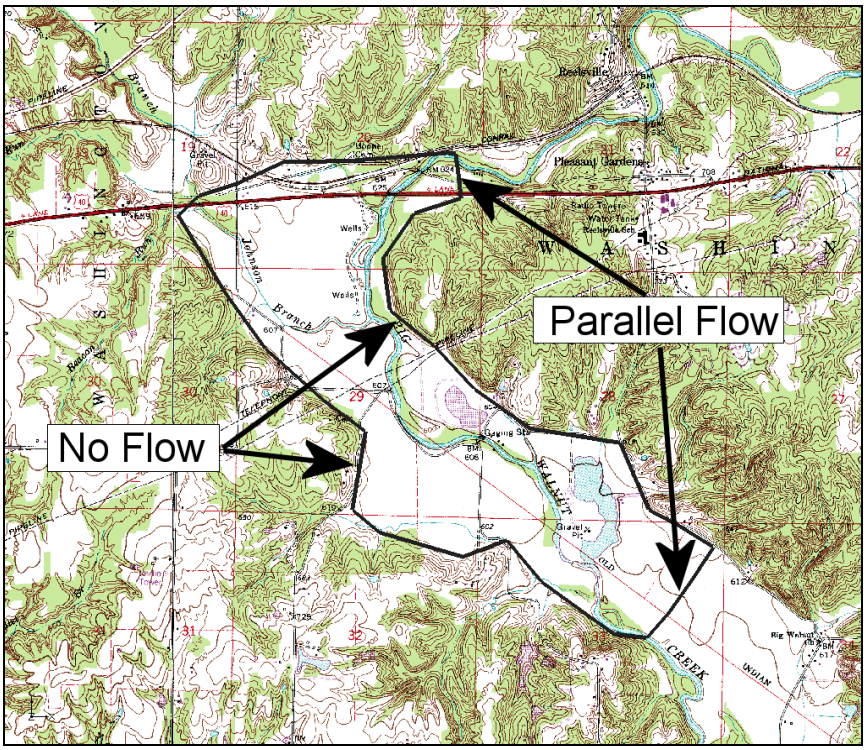

Figure 1 Model boundary

The well field is situated in the floodplain of Big Walnut Creek. The aquifer is composed of coarse gravel with an average hydraulic conductivity of 250 ft/d (60.9 m/d), deposited in a buried bedrock valley. Although the bedrock surrounding the valley is slightly permeable, it is not considered an important source of water. The thickness of the gravel aquifer in the valley varies from 10–80 feet (3.0–24.4 meters). At the wellfield, the ground elevation is roughly 600 feet (183 meters), and the aquifer is roughly 60 feet (18.3 meters) thick.

1.2 Getting Started

Do the following to get started:

1. If necessary, launch GMS.

2. If GMS is already running, select the *File* | **New** command to ensure that the program settings are restored to their default state.

2 Reading in the Background Map

The first step to create the model is to read in a background image of the site being modeled. Use the image as a guide while creating points, arcs, and polygons to define features of the model.

1. Select the **Open** macro to bring up the *Open* dialog.

2. Locate and open the directory entitled *Tutorials\MODAEM\modaem*.
3. Change the *Files of type* to "Images (*.tif; *.tiff; *.jpg; *.jpeg; *.png; *.sid)".
4. Select the file "brazil_topo.jpg" and click **Open** to import the image.

3 Defining the Units

At this point, also define the units used in the conceptual model. The chosen units will be applied to edit fields in the GMS interface as of reminder of the proper units for each parameter.

1. Select the *Edit* | **Units** command to open the *Units* dialog.
2. For *Length*, select the ... button next to the *Length* area to open the *Display Projection* dialog.
3. Change the *Units* to "Meters" for the *Vertical* units.
4. To check that meters are selected for the Horizontal units, click the **Set Projection** button next to *Global projection* to open the *Select Projection* dialog.
5. Go down to the *Planar units* drop-down menu and ensure that "Meters" are selected.
6. Click **OK** to exit the *Select Projection* dialog.
7. Click **OK** to exit the *Display Projection* dialog.
8. For *Time*, select "d" (for days). Ignore the other units (they are not used for flow simulations).
9. Click **OK** to exit the *Units* dialog.

4 Creating the Conceptual Model

It is now possible to enter the model data. First, create a MODAEM conceptual model. Second, create coverages to define the boundary conditions and aquifer properties. The boundary of the model is shown in Figure 2.

1. In the Project Explorer, right-click on the empty space then, from the pop-up menu, select the *New* | **Conceptual Model** command to open the *Conceptual Model Properties* dialog.
2. Change the *Name* to "Indiana".
3. Change the *Type* to "MODAEM".

4. Click **OK** to close the *Conceptual Model Properties* dialog.
5. Right-click on the "Indiana" conceptual model, then select the **New Coverage** menu command to open the *Coverage Setup* dialog.
6. Change the *Coverage name* to "Boundary".
7. Select the *Use to define model boundary* option.
8. Click **OK** to close the *Coverage Setup* dialog.
9. Select the "Boundary" coverage.
10. Using the **Create Arc** tool, click out the boundary as shown in Figure 2 below.

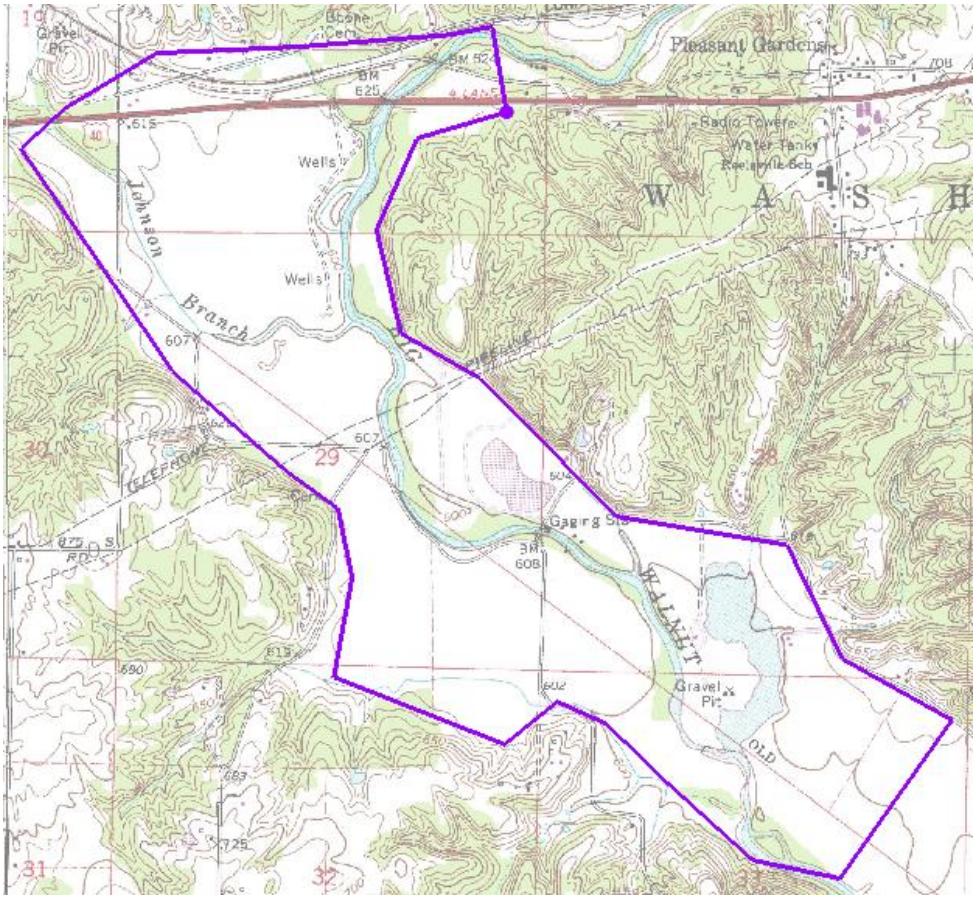

Figure 2 Boundary arcs

5 Creating the Specified Head Arcs

By default, the arcs in a MODAEM boundary coverage are "no flow" boundaries. This means the arc's type is set to "specified flow" and that the flow is set to 0. Next, add

specified head arcs to this coverage. To create the specified head arcs, split the boundary arc into four separate arcs.

5.1 Convert Vertices to Nodes

1. Select the **Display Options** macro to open the *Display Options* dialog.
2. On the left side of the dialog, make sure that *Map Data* is selected then turn on the *Vertices* option.
3. Click **OK** to close the *Display Options* dialog.
4. Use the **Select Objects** tool to select the four points (vertices and/or nodes) displayed in Figure 3 below. To select more than one point, hold the *Shift* key while selecting.

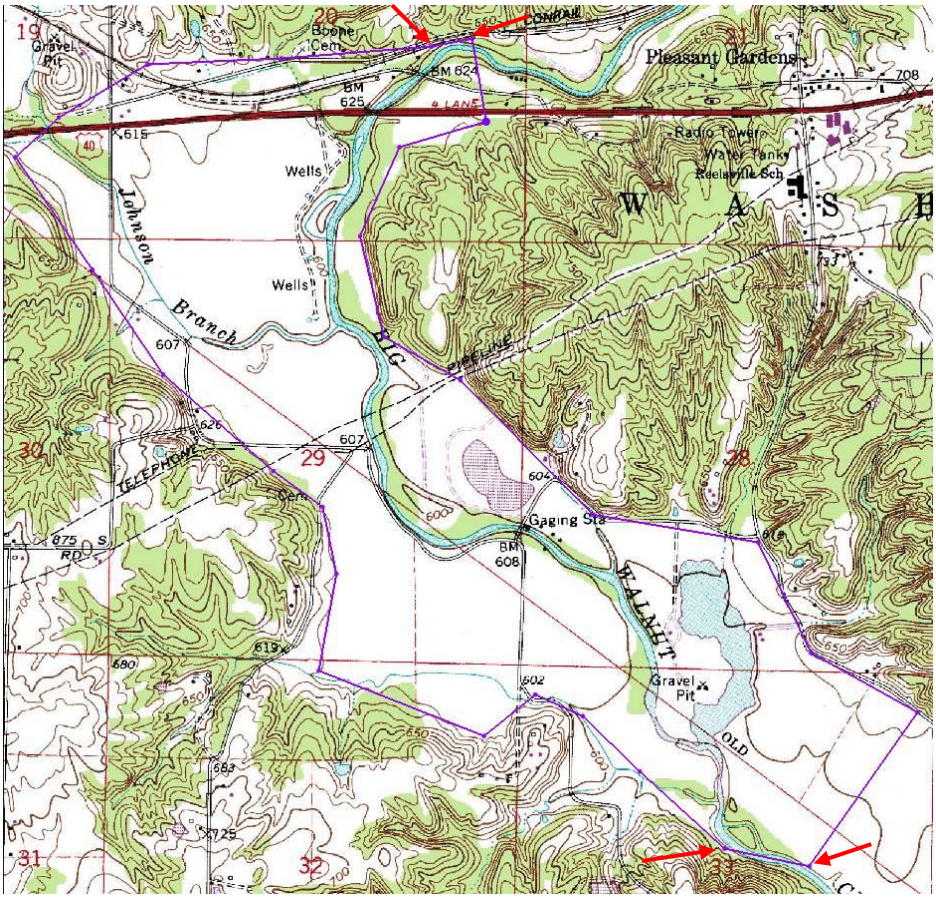

Figure 3 Convert vertices to nodes

It may be necessary to insert additional vertices. This can be done by using the **Create Vertex** tool. Simply select the tool and then click on the arc in the desired location. Also, depending on how the boundary arc was created, one of the vertices shown in the figure above may actually be a node. In that case, the node can be selected with the

Select Vertex tool. If there is a node at one of the locations shown above, just select the other three vertices.

5. Select the *Feature Objects* | **Vertices → Nodes** command to convert all the selected vertices to nodes.

5.2 Assigning Arcs

1. Using the **Select Arcs** tool, select the two new arcs that were created on the north and south of the boundary.

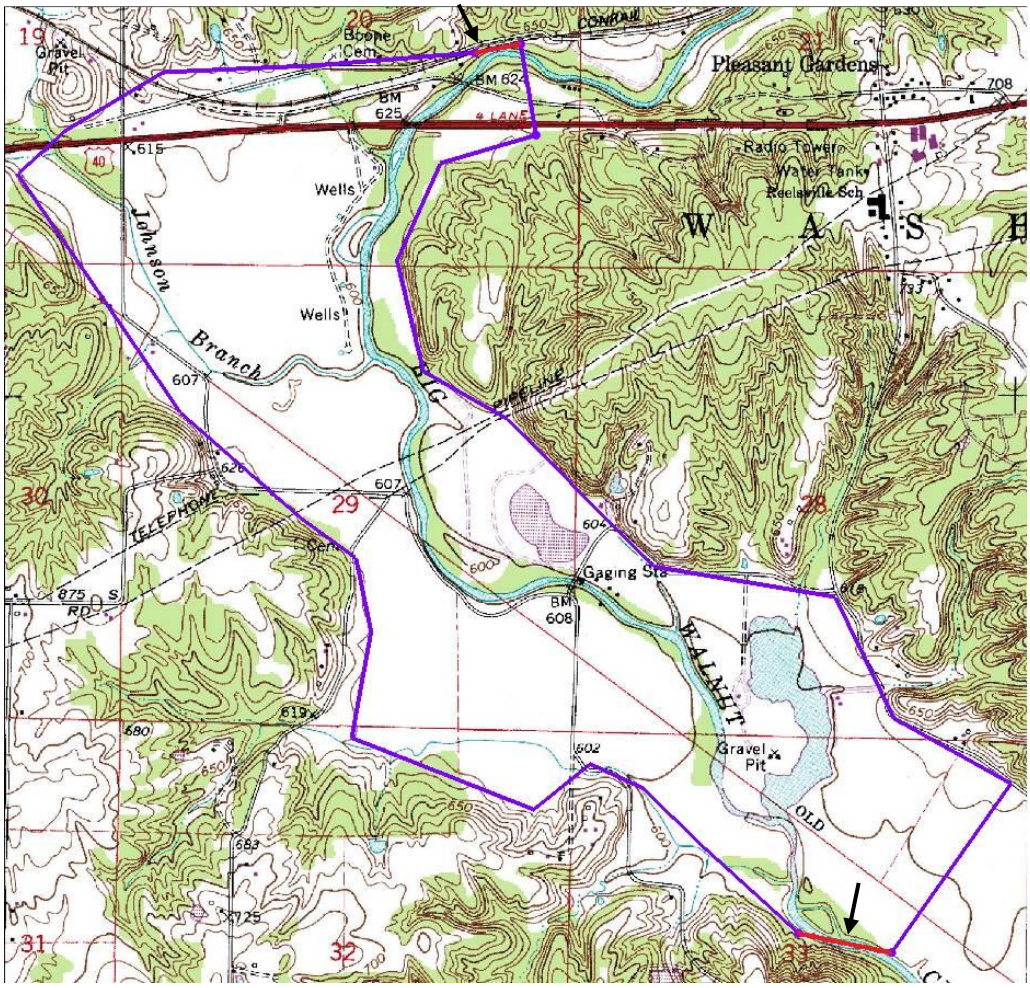

Figure 4 Specified head arcs

2. Select **Properties** button to open the *Attribute Table* dialog.

3. In the *All* row, change the type to "spec. head".

4. Select **OK** to exit the *Attributes Table* dialog.

5. Using the **Select Points/Nodes** tool, select both nodes on the northern specified head arc. To select more than one node, hold the *Shift* key down while clicking or drag a box around both nodes.

6. Select the **Properties** button to open the *Attribute Table* dialog.

7. Change the *BC type* to "spec. head".

8. In the *Head* field for both nodes, enter "182.0".

9. Select **OK** to exit the *Attributes Table* dialog.

10. Repeat steps 5–9 for the nodes attached to the southern specified head arc, but enter "178.6" for the *Head* value.

6 Entering the Aquifer Properties

Next, enter the properties of the aquifer. Aquifer properties can be assigned to individual polygons, and also define properties for a background aquifer.

1. Select the *MODAEM* | **Global Options** command to open the *MODAEM Global Options* dialog.

2. In the *Background aquifer properties* section, enter the following values:

   - "170.0" for the *Base*
   - "18.0" for the *Thickness*
   - "60.0" for the *Hyd. cond.*

3. Select **OK** to exit open the *MODAEM Global Options* dialog.

With a boundary coverage, a single polygon must define the aquifer being modeled.

4. Select the *Feature Objects* | **Build Polygons** command.

7 Saving the Project

It is now possible to run MODAEM. With other models in GMS, like MODFLOW for example, it's necessary to first save the changes to the project before running the model. When running MODAEM, however, the data currently in memory is written to temporary files that MODAEM reads to compute its solution. Therefore, there isn't a need to save the changes in GMS before running MODAEM. However, it's a good idea to save the work periodically anyway, so do that now.

1. Select the *File* | **Save As** command to open the *Save As* dialog.

2. Change the *File name* to "brazil" then click **Save.**

It is recommended to use the **Save** button periodically as the model is developed.

8 Running MODAEM

Now to run MODAEM. This can be done by selecting the menu command *MODAEM* | **Solve** or by hitting the *F5* key. Once this command is executed, a dialog will appear showing the output from the MODAEM model.

1. Select *MODAEM* | **Solve** to launch the *MODAEM* model wrapper.
2. When *MODAEM* is finished, select the **Close** button.

Head contours should now appear inside the boundary coverage.

3. Select the **Contours** macro to open the *Dataset Contour Options – Map – MODAEM Head* dialog.
4. Change the *Contour method* to "Color Fill and Linear".
5. Under the *Fill options* section of the dialog, change the *Transparency* value to "40".
6. Select **OK** to close the *Dataset Contour Options – Map – MODAEM Head* dialog.

9 Creating the River

Now to add the river to the model.

1. Right-click on the "Indiana" conceptual model in the Project Explorer.
2. Select the **New Coverage** option to open the *Coverage Setup* dialog.
3. Change the name of the coverage to "River".
4. Under the *Source/Sink/BCs* section, turn on the *River* option.
5. Select **OK** to exit the *Coverage Setup* dialog.
6. Select the **Create Arc** tool and click out the river arc starting near the northern specified head boundary and ending near the southern specified head boundary, as shown in Figure 5 below. Don't extend the river beyond the boundary coverage.

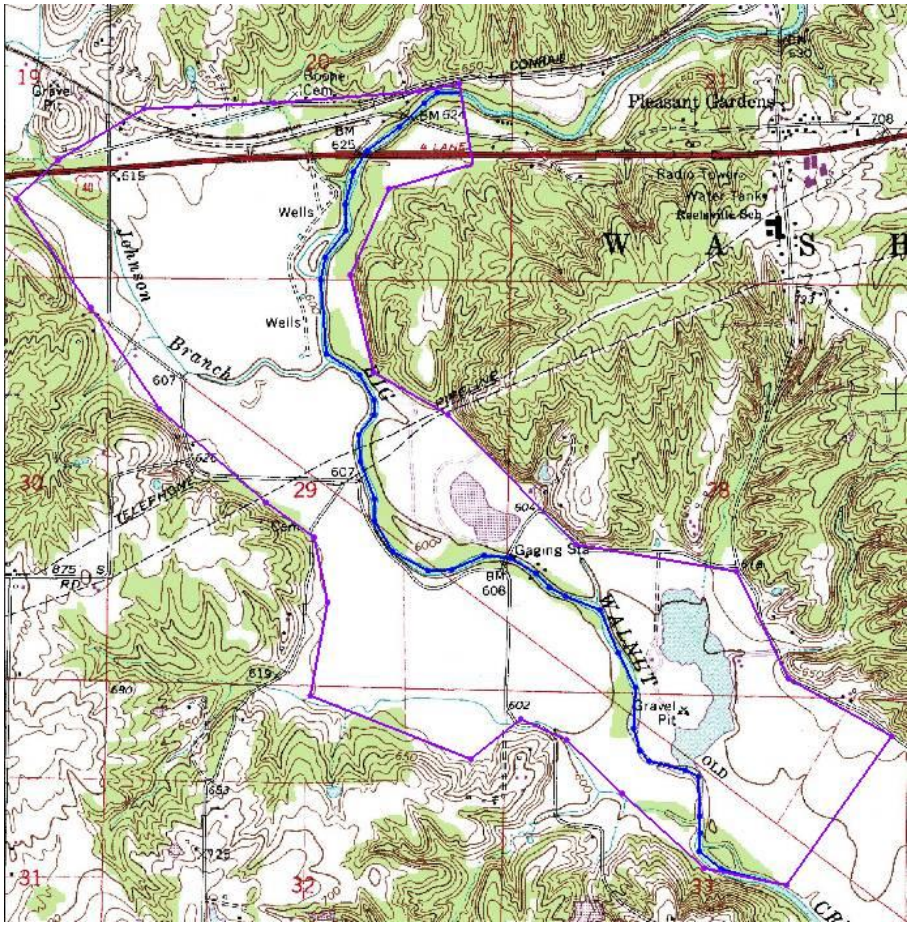

Figure 5 Modeling the river

7. Using the **Select Arcs** tool, click anywhere on the river arc to select it.
8. Select **Properties** button to open the *Attribute Table* dialog.
9. Change the type of the arc to "river".
10. Enter a value of "5000.0" for the *Cond.* (conductance).
11. Click **OK** to close the *Attributes Table* dialog.
12. Using the **Select Points/Nodes** tool, double-click on the river node at the northern end of the model to open the *Attribute Table* dialog.
13. Enter "182.0" for the *Head.*
14. Enter "179.0" for the *Elev*.
15. Select **OK** to exit the *Attribute Table* dialog.
16. Repeat the same process for the southern river node (steps 14–17), but enter "178.6" for the *Head* and "175.6" for the *Elev*.

10 Running MODAEM

It is now possible to run MODAEM again.

1. Select *MODAEM* | **Solve** to launch the *MODAEM* model wrapper.
2. When *MODAEM* is finished, select the **Close** button.

Notice some change in the head contours, particularly around the river arc.

11 Adding Recharge

Now to add recharge to the model.

1. Right-click on the "Boundary" coverage and select the **Duplicate** command.
2. Double-click on the new coverage (called "Copy of Boundary") to bring up the *Coverage Setup* dialog.
3. Change the *Coverage Name* to "Recharge".
4. In the *Sources/Sinks/BCs* section of the dialog, turn off *Specified Head* and *Specified Flow*.
5. In the *Areal Properties* section of the dialog, toggle on *Recharge*.
6. Select **OK** to exit the *Coverage Setup* dialog.
7. Using the **Select Polygons** tool, double-click on the polygon to open the *Attribute Table* dialog.
8. Assign a value of ".00042" to the *Recharge* field.
9. Click **OK** to exit the *Attribute Table* dialog.

12 Running MODAEM

It is now possible to run MODAEM again.

1. Select *MODAEM* | **Solve** to launch the *MODAEM* model wrapper.
2. When *MODAEM* is finished, select the **Close** button.

13 Production Wells

Now to import production wells from a tab-delimited text file.

1. Right-click on "Indiana" in the Project Explorer and select the **New Coverage** option to open the *Coverage Setup* dialog.
2. Change the *Coverage name* to "Wells".
3. Under the *Source/Sink/BCs* section, turn on the *Wells* option.
4. Select **OK** to exit the *Coverage Setup* dialog.
5. Select the **Open** macro to bring up the *Open* dialog.
6. Locate and open the directory entitled *Tutorials\modaem*.
7. Change the *Files of type* to "All Files (*.*)".
8. Select the file "prod_wells.txt".
9. Click **Open** to start the *Text Import Wizard*.
10. Turn on the *Heading row* toggle.
11. Click the **Next** button to move to the next step in the *Text Import Wizard*.
12. Change the *GMS data type* to "Well data".
13. In the *File preview* section of the dialog, change the following values:
    - The *Type* of the first column to "X"
    - The *Type* of the second column to "Y"
    - The *Type* of the third column to "Flow Rate"
14. Select the **Finish** button to exit the *Text Import Wizard* dialog.

There may be some difficulty in seeing the wells. The well symbol can be changed in the *Display Options* dialog by clicking on the **Display Options** macro and then changing the color of the symbol for *Well* in the *Coverage* section.

14 Observation Wells

Before running MODAEM again, read in field-measured head values.

1. Right-click on "Indiana" in the Project Explorer and select the **New Coverage** option to open the *Coverage Setup* dialog.
2. Change the *Coverage name* to "Observation".
3. Under the *Observation Points* section, turn on the *Head* option.

4. Select **OK** to exit the *New Coverage* dialog.
5. Select the **Open** button to bring up the *Open* dialog.
6. Locate and open the directory entitled *Tutorials\modaem*.
7. Select the file "well_head.txt".
8. Click **Open** to start the *Text Import Wizard*.
9. Turn on the *Heading row* option.
10. Click the **Next** button to move to the next step of the *Text Import Wizard*.
11. Change the *GMS data type* to "Observation data".
12. In the *File preview* section of the dialog, change the following values:
    - *Type* of the first column to "Name"
    - *Type* of the second column to "X"
    - *Type* of the third column to "Y"
    - *Type* of the fourth column to "Obs. Head"
13. Select the **Finish** button to exit the *Text Import Wizard* dialog. The observation targets should appear.

15 Running MODAEM

Now to run MODAEM again.

1. Select *MODAEM* | **Solve** to launch the *MODAEM* model wrapper.
2. When *MODAEM* is finished, select the **Close** button.

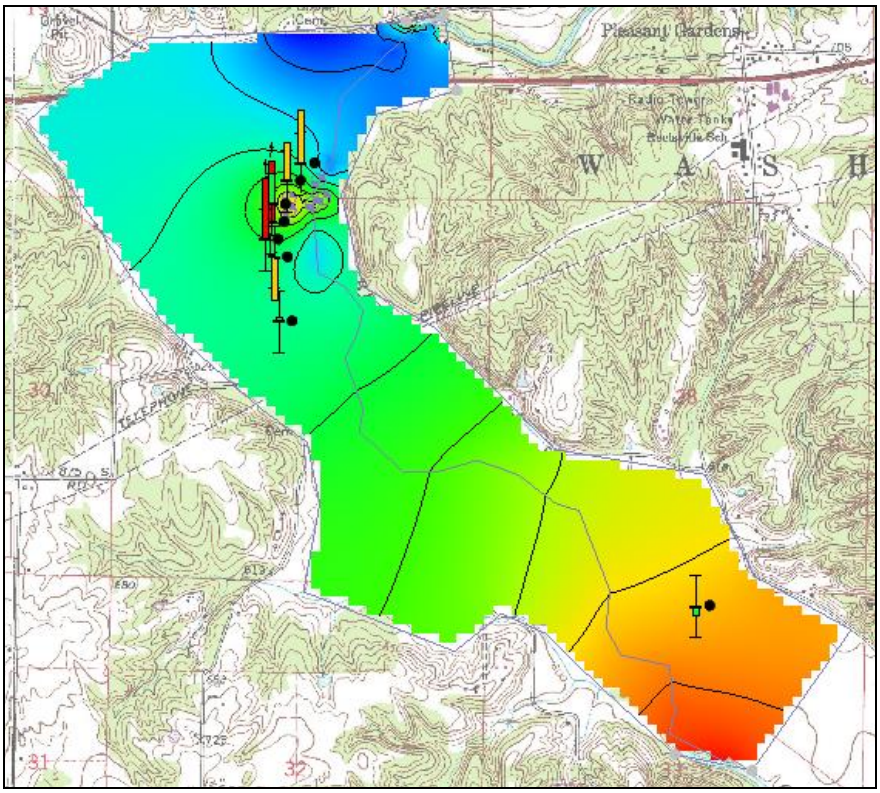

Figure 6 Final MODAEM run

16 Conclusion

This concludes the tutorial. Here are the key concepts in this tutorial:

- MODAEM is an analytic element model, and it uses points, arcs, and polygons to compute solutions.
- The Map module is used to construct conceptual models using feature objects (points, arcs and polygons).
- Feature objects are grouped into coverages. Only one coverage can be active, and only the active coverage can be edited.